Request for Information (RFI) on Low-Energy Beta Particle Detection

IARPA-RFI-21-04

In order to make a generational leap in fieldable low-energy beta particle detection, IARPA is interested in assessing potential, new technological solutions.

Background

Radioisotopes emitting low-energy beta particles[1] have been used in research as tracers in studies of metabolism and other biological processes.[2,3] Beta radiation sources are also common in nuclear medicine.[4] Additionally, the detection of low-energy beta particles is of interest in the monitoring of nuclear facility operations and decommissioning and related environmental effects.[5,6]

Low-energy beta particles have been traditionally measured by employing liquid scintillation or gas proportional counter technologies. Existing methods are capable of demonstrating high sensitivity but suffer from a number of limitations when considering requirements for autonomous operation of small, ruggedized portable systems that equal or exceed fixed-site measurement performance.

Liquid Scintillation Counting (LSC) has been used since the 1950's to improve beta particle measurement efficiency.[7] For beta decay, electron energies are approximately one-third, on average, the end point energy. The penetration range of these particles varies by material but is generally very short (e.g., less than 1 cm in air for low energies).[8] This short particle range hampers beta detection efficiency due to energy loss from sample self-absorption and attenuation. LSC partially mitigates these intrinsic challenges by incorporating the radioisotope sample into a suitable liquid scintillation solution for measurement. Due to the low light output and typical readout using a photo-multiplier tube (PMT), this method is very sensitive to backgrounds that arise from single-electron sources. Improved methods, such as multiple, higher-efficiency PMTs, have led to laboratory systems with counting efficiencies as high as 90%. However, for low-level environmental sampling, the capability to deploy this technology for ultra-trace measurements is severely limited due by the sample preparation process, the need for a high-voltage source, and the need for background shielding.[9]

Proportional counting, in use since the 1940's, is another standard technique for low-energy beta measurements. This method measures radioisotope samples in gaseous form. The detector

1 AKA electrons. Consider low energy to mean the range from a few keV to a few hundred keV.

2 Kawachi, 2011, https://doi.org/10.13140/2.1.2427.7447

3 Gordon, 1994, https://doi.org/10.1109/23.322937

4 Jodal, 2009, https://doi.org/10.1080/02841860802245163

5 Bryn A Bridges 2008 J. Radiol. Prot. 28 1

6 Eyrolle, 2018, https://doi.org/10.1016/j.jenvrad.2017.11.001

7 Warwick, 1990, https://doi.org/10.1039/AP9902700109

8 Katz and Penfold, 1952, https://doi.org/10.1103/RevModPhys.24.28

9 Knoll, Radiation Detection and Measurement, 4th Ed.

technology is based on gas multiplication in a detector that consists of a metal tube (cathode) of a few centimeters in diameter with an anode wire drawn down the length of the volume. The tube is filled with an ionizable gas (typically flammable) plus the target sample gas and held at a bias, typically a few thousand Volts. When operated in proportional mode, incident radiation ionizes the gas volume, and the electrons are measured on the anode proportionally to the energy of the incident radiation.[10] While this technology is widely used, limitations for high-sensitivity field applications include the need for significant shielding, the need for a high-voltage source, and the need for continuous flow of filler gas, necessitating flammable gas supplies.

Scope

Responses to this RFI are asked to address the following questions targeting a specific approach or concept, sorted into three categories: (a) detection technology, (b) physical properties, and (c) data management and analysis.

Detection technology for low-energy beta particles:

- a1. What is the technology basis for low-energy beta measurement that you recommend (e.g., scintillation, charge collection, other)?
- a2. For a source energy or energies, is there an inherent resolution that can be assigned in terms of keV FWHM?
- a3. What sample form(s) can be accommodated (e.g., aqueous, gas, other)?
- a4. What is the active sensitive sensor area/volume, or range of areas/volumes? What aspects of the detection technology impact potential sample interface?
- a5. Define the theoretical and measured (if available) beta detection efficiencies in the following energy ranges: 0.1keV-20keV (state low-energy threshold if not 0.1keV), 20-100keV, 100-500keV, 500keV-1MeV, above 1MeV.
- a6. What are the primary radioactive background considerations for this technology? What is the assignable detector system background (beta and otherwise) in the energy ranges 0.1-20keV (state lower limit if not 0.1keV), 20-100keV, 100-500keV, 500keV-1MeV, above 1 MeV.
- a7. Does the technology possess intrinsic background mitigation?
- a8. What is the impact of no external background shielding on detection efficiency for this specific technology?
- a9. Is there an inherent sensor function degradation or lifetime on the time scale of six months? Has the technology previously demonstrated long-term operation?
- a10. How sensitive is the intrinsic detection technology to temperature fluctuations?

System Physical Properties:

- b1. Does the technology require a high-voltage source? A low-voltage source? If yes, please specify the required voltage.
- b2. What are the power requirements for a representative detector volume or system? (As in for a detector of normal size “X”, how many watts are required to operate the system?)

10 Leo, W.R. Techniques for Nuclear and Particle Physics Experiments, Second Revised Edition.

b3. Does the technology require cooling or heating of any components? If yes, what are the implications of such temperature conditioning in SWaP?
b4. What are the current or expected lower limits on size/weight of a detector module with the technology based on the answers for the beta detection efficiencies and background considerations addressed in the previous section?
b5. What consumables (e.g., gas, liquid, other) would be required for a stand-alone detection system?
b6. What are the operating conditions for a final, fully packaged system with respect to external temperature and pressure? Are there any other relevant environmental parameters that would impact system performance?
b7. Are there routine maintenance requirements for the detector technology or a detection system based on the targeted technology?
b8. How compatible is the technology with autonomous operation?

Data Management and Analysis:

c1. How is the detector information extracted (analog, digital)?
c2. How is the data reported, and is there a specific data format (waveforms, gates, etc.)?
c3. What is the data volume for a representative measurement period? The purpose of this question is to understand the relative data volume requirements for this technology.
c4. Discuss required computational requirements and data processing to achieve final results?
c5. How is the system calibrated? How stable is calibration? To what measurement standard would the system be traceable to?
c6. What is a representative data readout period? Milliseconds? Hours?

In response to submissions to this RFI, IARPA may choose to organize a virtual, invitation-only workshop for the purpose of reviewing and discussing relevant current and future research. Should a workshop occur, participants will be asked to make formal presentations based on their RFI submissions. Written submissions and information discussed at a workshop may assist in the formulation of future U.S. Government research.

Preparation Instructions to Respondents:

IARPA requests that respondents submit responses to the above questions for use by the Government in formulating a potential program. IARPA requests that submittals briefly and clearly describe the potential approach or concept, outline critical technical issues/obstacles, describe how the approach may address those issues/obstacles and comment on the expected performance and robustness of the proposed approach. If appropriate, respondents may also choose to provide a non-proprietary rough order of magnitude (ROM) estimate regarding what such approaches might require in terms of funding and other resources for one or more years. This announcement contains all of the information required to submit a response. No additional forms, kits, or other materials are needed.

IARPA welcomes responses from all capable and qualified sources from within and outside of the U.S.

Responses must meet the following formatting requirements:

1. A one-page cover sheet that identifies the title, organization(s), respondent's technical and administrative points of contact - including names, addresses, phone and fax numbers, and email addresses of all co-authors, and clearly indicating its association with RFI-21-04;
2. A substantive, focused, one-half page executive summary;
3. Responses to the above questions covering, (a) detection technology, (b) physical properties and, (c) data management and analysis. This section should be limited to 5 pages in minimum 12 point Times New Roman font, appropriate for single-sided, single-spaced 8.5 by 11 inch paper, with 1-inch margins;
4. A list of citations (any significant claims or reports of success must be accompanied by citations).

Submission Instructions to Respondents:

Responses to this RFI are due no later than 5:00 p.m., Eastern Time, 28 May, 2021. All submissions must be electronically submitted to dni-iarpa-rfi-21-04@iarpa.gov as a PDF document. Inquiries to this RFI must be submitted to dni-iarpa-rfi-21-04@iarpa.gov. Do not send questions with proprietary content. No telephone inquiries will be accepted.

Disclaimers and Important Notes:

This is an RFI issued solely for information and planning purposes and does not constitute a solicitation or authority to enter into negotiations for a contract. Respondents are advised that IARPA is under no obligation to acknowledge receipt of the information or to provide feedback to respondents with respect to any information submitted under this RFI. Responses to this notice are not offers and cannot be accepted by the Government to form a binding contract. Respondents are solely responsible for all expenses associated with responding to this RFI. IARPA will not provide reimbursement for costs incurred in responding to this RFI. It is the respondent's responsibility to ensure that the submitted material has been approved for public release by the information owner. The Government does not intend to award a contract on the basis of this RFI or to otherwise pay for the information solicited, nor is the Government obligated to issue a solicitation based on responses received. **No proprietary and no classified concepts or information shall be included in the submittal.** However, should a respondent wish to submit classified concepts or information, prior coordination **must** be made with the IARPA Chief of Security. Email the Primary Point of Contact with a request for coordination with the IARPA Chief of Security. Input on technical aspects of the responses may be solicited by IARPA from non-Government consultants/experts who are bound by appropriate non-disclosure requirements.

Contracting Office Address:

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